Information, Alternative Markets, and Security Price Processes: A Survey of Literature

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This Version
November 15, 2002
(Comments Welcome)

Abstract

In this paper, we survey a wide range of theoretical and empirical papers on derivatives markets to address the information contents of trading activities in derivatives markets. Both theoretical and empirical research on options market and futures market indicate that the presence of alternative markets may be a factor for informed traders' presence in one of or in both markets to trade on their information. One group of researchers support the hypothesis that information reflects in derivatives market first and underlying stock market lags in information transmission. Another group of researchers support the hypothesis that information reflects in stock markets first and trading activities in derivatives markets are not significant. Since researchers are not in agreement in this issue, it raises a potential for further research on different activities of derivatives market.

JEL Classification Code: C16, C31, C51, C52, C53, G11, and G13.

Key Words : Open Interest, Volume, Market Efficiency, Information Traders.

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1.0 Introduction

Prices and trading activities in security markets provide information about future price movements. The presence of derivatives markets is not only an alternatives markets for trade, but also a reason for traders with superior information. Derivatives instruments, in fact, are not derivative, they constitute an additional venue for the informed traders to trade on their information and others to discover that information. Derivatives may lead the underlying assets in impounding information and they may provide information that simply cannot be inferred from the markets in underlying assets.

With the introduction of option markets, informationally motivated traders as well as liquidity traders have an additional venue to meet their trading needs. In fact, informed traders may find option markets more lucrative than the stock market due to lower transaction costs, less capital outlays, higher leverage, limited loss potential and lesser trading restrictions (e.g., no uptick rule for shorting).[2] If informed traders do choose to trade in option markets, not only the option prices and option markets activity become relevant in impounding the information and its subsequent discovery, options could in fact lead the underlying stock in terms of price change and trading activity.

Before we present the literature review, we like to address some issues first. Option-trading activities are informative. Investors who trade in option markets provide information about the probable closing stock price at the option maturity date through their trading activities. Investors who observe these trading activities can retrieve the information content of option markets and predict the stock price movements well ahead of the maturity date. For example, one can forecast the movements of stock prices in the range of one to three weeks before the option maturity date in any option month. In other words, one can observe activities in different strikes of calls and puts on an underlying stock in the option markets from the first day of the option month. After observing these activities for about a week, he can assign different probability measure on each strike of calls and puts and can calculate a probable stock price that is expected to be the true stock price at the maturity date. He can also follow the

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[2] Black (1975) first hinted to the attractiveness of the options market to informed traders.

same procedure just about a week before the maturity date to predict the stock price for the underlying security.

There are different types of financial markets, such as stock market and different types of derivatives markets, where investors may trade. It may also be true that some investors prefer to trade stock, some investors options, some investors futures and some in all of them. Normally, sophisticated investors have the privilege to trade in derivatives markets. Among these sophisticated investors, most of them are institutional investors who have access to large financial and other forms of resources. In our research, we assume that option-trading activities, which are mostly dominated by sophisticated investors, on each underlying security reflect all participating investors’ beliefs about the possible movements of underlying stock prices by the option maturity date. We observe that as the option maturity date approaches, actual stock prices tend to move toward the prices implied in the activities of options trading. This suggests that those investors know the probable movements of the underlying stock prices ahead of other investors who may or not trade other markets (other than the stock market).

One interesting observation we like to point out is that these option-trading activities are public information. All previous option activities are shown as open interests attached with each strikes of calls and puts for each option maturing month and daily activities are observed through the daily volumes of calls and puts on each strikes for each option month. Although, investors who do not trade in the option market but at least can observe these trading activities well before the option maturity date, they do not seem to incorporate the information content of those trading activities into their expectations. As a result, it takes a while before the actual stock price moves toward the stock price implied in the option trading activities. Hence it seems to us that may be not all investors can observe these activities, or even though they can observe them, not all investors can retrieve the information from those trading activities, or there are differences in opinions about the value of any information among investors and the like. Whatever the case may be, it apparently makes us believe that there is a gap in price adjustments processes for securities when they are traded in different markets in different forms and all available information are not reflected in the equilibrium prices on the same securities in different markets instantaneously and simultaneously.

In the second part of the literature review, we, therefore, decided to pose some related questions:

1. Can the financial market consist of investors with different level of information? Or can there be some investors with superior information? Why?
2. Can there be differences of opinions amongst investors so that it may take some times to reflect the true value of that information in security prices?
3. Can there be any preferences or reasons of market places, such as option market or stock market, for information trading by any informed traders? Why??
4. Can the information trading be identified? How?
5. If other investors can identify the information trading, can these investors also benefit from following the information trading?
6. If there are any preferences of markets, is the information trading in one market followed by trading in other market?

2. The Review of the Theoretical Information Models: Derivatives Markets

In a market where traders have different information, the market maker faces a severe adverse selection problem: Because the identity of incoming orders is unknown, the market maker sets a spread to compensate for the loss that could occur from trading with a better-informed trader. In option markets, the information flow incorporates data about the price or expected return and the volatility of the underlying asset.

As such, the bid-ask spread in the option market reflects both information components. Theoretical models of market microstructure that focus on the informational role of the options market are relatively small compared to that of the stock market. Easley, O’Hara, and Srinivas (1998), (which first appeared as a working paper in 1993), to our knowledge, is the first asymmetric information model that investigates the informational role of transactions volume in options markets.

2.1.1 Informational Linkage Models: Options Markets

Easley *et al.* (1998) develop a sequential trade model in the spirit of Easley and O"Hara (1987), where traders choose to transact in option or security markets with risk neutral, competitive market makers. In the model, there is an asset that trades in an equity market and options on that security, which trade in an options market. The asset's future value at time T is given by the random variable, V, where, $V \in \{\underline{V}, \overline{V}\}$. An information event is defined as a signal, ψ, about V, where the signal can take one of two values, *L* and *H*. The probability that the value is low is δ, with (1-δ) the corresponding probability that the signal is high. The value of the asset conditional on the signal is $\underline{V} \quad if \quad \Psi = L \quad or \quad \overline{V} \quad if \quad \Psi = H$. If no information event has occurred, then the expected value of the asset remains at its unconditional level, $V^* = \delta \underline{V} + (1 - \delta)\overline{V}$. Information events need not occur every day, reflecting that in markets it is not generally known whether other traders are actually trading on the basis of new information. It is assumed that exactly one information event will occur, and that the probability of occurrence before the start of trade on day *j*, conditional on an information event not having already occurred, is η_j.

If an information event occurs, fraction μ of the universe of traders is informed; if no information event occurs, by definition all traders are uninformed. A trade consists of a single round lot of stock equaling γ shares or a single option contract controlling θ shares of a stock. Two European option contracts are considered: a put option contract with expiration date *J* and exercise price *X*, and a call option with expiration date *J* and exercise price *Y*. At each time t in a trading day, each market maker sets prices to yield zero expected profit conditional on the security or contract being traded. Let the history of trade and transaction prices in the options and stock markets to time t is h_t. Thus, h_t consists of t observations of trades and their transaction prices. Let the propensity of the uninformed to buy or sell stock or options is determined by the stochastic process:

$$\begin{aligned}
&\Pr\{\, buy\ stock\ at\ t \text{ I } h_{t-1} \} = a_t(h_{t-1});\\
&\Pr\{\, sell\ stock\ at\ t \text{ I } h_{t-1} \} = b_t(h_{t-1});\\
&\Pr\{\, buy\ \ put\ at\ t \text{ I } h_{t-1} \} = c_t(h_{t-1});\\
&\Pr\{\, sell\ \ put\ at\ t \text{ I } h_{t-1} \} = d_t(h_{t-1});\\
&\Pr\{\, buy\ call\ at\ t \text{ I } h_{t-1} \} = e_t(h_{t-1});\\
&\Pr\{\, buy\ sell\ call\ at\ t \text{ I } h_{t-1} \} = f_t(h_{t-1});
\end{aligned}$$

Where for each time t, $a_t(h_{t-1}), b_t(h_{t-1}), c_t(h_{t-1}), d_t(h_{t-1}), e_t(h_{t-1}), f_t(h_{t-1})$ are measurable functions of the history h_{t-1}, are all positive, and sum to one. There is no trading history for the day prior to the first trade of the day. So let $a_1(h_{-1}) = a$, $b_1(h_{-1}) = b$, $c_1(h_{-1}) = c$, $d_1(h_{-1}) = d$, $e_1(h_{-1}) = e$, and $f_1(h_{-1}) = f$. The only restriction placed on uninformed trade is that an option trade at time t does not change the probabilities of uninformed trade at time $t+1$; i.e., $a_t(h_{t-1}) = a_t(h_{t+1})$ and so on, if $h_t = (h_{t-1}$, option trade$)$.

The informed trader's decision problem can be specified as follows. If the trader knows that $V = \underline{V}$, then her profit is given by:

$$\underline{\pi} = \begin{bmatrix} (b_s - \underline{V})\gamma & if\ sell\ the\ stock, \\ -a_p + \theta\,(X - \underline{V}) & if\ buy\ a\ put, \\ b_c & if\ sell\ a\ call \end{bmatrix}$$

If the trader knows that $V = \overline{V}$, then her profit is given by:

$$\overline{\pi} = \begin{bmatrix} (-a_s + \overline{V})\gamma & if\ buy\ the\ stock, \\ b_p & if\ sell\ a\ put, \\ -a_c + (\overline{V} - Y)\theta & if\ sell\ a\ call \end{bmatrix}$$

Given an opportunity to trade, the informed trader selects the trade that maximizes her profit given her information. We denote by α_v the fraction of traders informed of V who chooses to trade in the security market, and by β_v the fraction of traders informed of V who choose to use calls given that they trade in option markets.

The market makers' price to buy or sell any contract will be its conditional expected value given the specific trade that occurs. Calculation of these conditional expected values follows from a standard application of Bayes' Rule, and it results in the following bid and ask prices for

$$b_s = E[V \,\mathrm{I}\, Sell\ stock] = \frac{\underline{V}\eta_1\delta\left(\mu\beta_{\underline{v}} + (1-\mu)b\right) + \overline{V}\eta_1(1-\delta)b(1-\mu) + V*(1-\eta_1)b}{\eta_1\left(\delta[\mu\alpha_{\underline{v}} + (1-\mu)b\right) + (1-\delta)b(1-\mu)] + (1-\eta_1)b}$$

$$a_s = E[V \,\mathrm{I}\, buy\ stock] = \frac{\underline{V}\eta_1\delta\left((1-\mu)a\right) + \overline{V}\eta_1(1-\delta)(\mu\alpha_{\overline{V}} + (1-\mu)a + V*(1-\eta_1)a}{\eta_1\left(\delta[(1-\mu)a + (1-\delta)\right)(\mu\alpha_{\overline{V}} + (1-\mu)a] + (1-\eta_1)a}$$

the first trade of day 1:

The bid and ask prices in the options market will also be conditional execrated values. The call option gives the holder the right to buy the stock at time J for price Y. If a high information event has occurred, the call option is worth $\theta\left(\overline{V} - Y\right)$. If there has been no new information, then the call is worth its expected value. The bid price for the call option will be the conditional expected value of the call given that a trader wishes to sell the call to the market maker. This is given by

$$b_c = E[Value\ of\ Call \,\mathrm{I}\, Sell\ Call] = 0\,\Pr\{\underline{V}\mathrm{I} Sell\ Call\} + \left(\overline{V} - Y\right)\theta\,\Pr\{\overline{V}\mathrm{I} Sell\ Call\} +$$
$$\left(\delta.0 + (1-\delta)\left(\overline{V} - Y\right)\theta\right)\Pr\{\Psi = 0\mathrm{I} Sell\ Call\}.$$

Calculating the conditional probabilities yields the bid for first call trade on day 1:

$$bc = \frac{\left(\overline{V} - Y\right)\theta(1-\delta)f(1-\eta_1\mu)}{\eta_1\left[(1-\delta)(1-\mu)f + \delta\left(\mu\left(1-\alpha_{\underline{v}}\right)\beta_{\underline{v}}\right) + (1-v)f\right] + (1-\eta_1)f}$$

The put gives the holder the right to sell the asset at time J for price X. Given the terminal values, the ask price for the put is expected value given that a trader wishes to buy the put. This is given by

$$a_p = E\left[\mathit{Value\ of\ \ put}\ \mathrm{I}\ \mathit{Buyput}\ \right] = \theta\left(X - \underline{V}\right)\Pr\left\{\underline{V}\mathrm{I}\mathit{Buy\ \ put}\right\} + 0.\Pr\left\{\overline{V}\mathrm{I}\mathit{Buy\ \ put}\right\} +$$
$$\left(\delta\theta\left(X - \underline{V}\right) + \left(1 - \delta 0\right)\right)\Pr\left\{\Psi = 0\mathrm{I}\mathit{Buy\ \ put}\right\}$$

Again, an application of Bayes' Rule yields an ask price for the first put on day 1 of

$$a_p = \delta\theta\left(X - \underline{V}\right)\bullet\frac{\eta_1\mu\left(1-\alpha_{\underline{v}}\right)\left(1-\beta_{\underline{v}}\right)+\eta_1\left(1-\mu\right)c}{\eta_1\left[\left(1-\delta\right)\left(1-\mu\right)c+\delta\left(\mu\left(1-\alpha_{\underline{v}}\right)\left(1-\beta_{\underline{v}}\right)+\left(1-\mu\right)c\right)\right]+\left(1-\eta_1\right)c}$$

Similar rules can be applied to develop an ask price for the call and a bid price for the put on the same day. At any time t, the notional price of the stock is

$$p_{st} = \gamma\left[\delta_t\underline{V} + \left(1-\delta_t\right)\overline{V}\right]$$

Where δ_t is the conditional probability of $\underline{V}$ given the history of trades. Similarly, the notional price of a put option is

$$p_{pt} = \theta\left(X - \underline{V}\right)\delta_t$$

and for the call it is

$$p_{ct} = \theta\left(\overline{V} - Y\right)\left(1-\delta_t\right)$$

From these pricing equations, the expected profit for each type of security can be calculated. The expected profit from selling a stock is

$$\frac{\gamma\left(1-\delta\right)\left(1-\eta_1\mu\right)b\left(\overline{V}-\underline{V}\right)}{\eta_1\delta\mu + b\left(1-\eta_1\mu\right)}.$$

The expected profit from selling the call is $\left(\overline{V}-Y\right)\theta\left(1-\delta\right)$, and the expected profit from buying the put option is $\left(X-\underline{V}\right)\theta\left(1-\delta\right)$. These profit conditions dictate that some informed traders will use options if

$$(\overline{V} - Y)\theta \ or \ (X - \underline{V})\theta > \frac{\gamma(1-\eta_1\mu)b(\overline{V} - \underline{V})}{\eta_1\delta\mu + b(1-\eta_1\mu)}$$

If the inequality holds, then at least some informed traders will choose to transact in the options market. This corresponds to a “pooling equilibrium” in that both liquidity traders and some informed traders will be pooled together in the options market. If the inequality does not hold, then no informed traders use options, leaving only liquidity traders in the options market. This is knows as “Separating equilibrium” in that the informed traders are separated from uninformed traders in the options market. Hence, where informed traders trade can be determined by looking at how market characteristics affect the profit from trading in each market. Increasing the market depth of the stock market or reducing the depth in the option markets results in more informed trading in stocks and the converse induces more informed trading in option markets. In an asymmetric world, a spread develops around the prior expected value of the asset generating profits from uninformed traders, which offset the losses to the informed traders for market makers. Given any first period trade, market makers update their beliefs, evaluate the probabilities on uninformed trade, and quote new price for subsequent trades in each market. This theoretical model, therefore, predicts that if options markets are venues for information-based trading then, in equilibrium, option trades of various types convey information on future stock price movements. This has been empirically tested in their paper and is discussed in the empirical literature survey.

John *et al*. (2000) develop a model, in the spirit of Glosten and Milgrom (1985), where agents can trade only in the stock market with no margin restrictions and then extended the model to consider the role of option trading. In addition, they analyze the impact on trading strategies and market prices in stock and option trading by introducing the margin requirements in the model. In their model, there are three types of traders in this market: informed traders, liquidity traders and a market maker. All traders are assumed to be risk neutral and the risk free interest rate is assumed to be zero. The informed traders receive signals about the stock’s future value and trade based this information. The liquidity traders are uninformed and have exogenous motives for trade such as portfolio rebalancing. The informed and liquidity traders trade with a competitive market maker who is assumed to set price rationally.

The stock value $\tilde{v}$ depends on the future state of the world $\theta \in [L, H]$. The stock values are given by v_L and v_H for $\theta = L$ and $\theta = H$, respectively, where $v_L < v_H$. The unconditional expected value of the stock is $\bar{v} = (v_L + v_H)/2$. The informed traders receive identical noisy private signals S about θ, which is either good news ($S = G$) or bad news ($S = B$). The precision of this signal is measured by the probability μ that it is accurate about the state θ, i.e., $Pr(\ S = G \,/\, \theta = H) = Pr(S = B \,/\, \theta = L) = \mu$. . In order to ensure that the signal is informative, we assume that $\mu > 0.5$ it is common knowledge. The market has a fraction α informed traders and 1-α liquidity traders. Informed traders are conjectured to submit a buy order on stock if they receive good news and a sell order if they receive bad news, i.e., their conjectured trading strategy is given by

$$X^{ss}(S) = \begin{Bmatrix} buy\ stock\ if\ \ S = G \\ sell\ stock\ if\ \ S = B \end{Bmatrix}$$

The market maker acts competitively and rationally to make zero profit by setting, in equilibrium, the bid price, $B_S^{ss} = E(\tilde{v}\ \mathrm{I} stock\ sale) = \bar{v} - \frac{\alpha(2\mu - 1)(v_H - v_L)}{2}$,

and ask price, $A_S^{ss} = \bar{v} + \frac{\alpha(2\mu - 1)(v_H - v_L)}{2}$, and the size of the spread is given by: $\Delta_S^{ss} = A_S^{ss} - B_S^{ss} = \alpha(2\mu - 1)(v_H - v_L)$. The size of the spread is increasing in α and μ. Assume now that traders have the choice of the stock or a put option on the stock with an exercise price of K where $v_L < K < v_H$. The put option provides date-3 payoffs of $K - v_L$ and 0 for the states $\theta = L$ and $\theta = H$, respectively. Informed and liquidity traders now split their trades between the stock and options market, where the split is exogenously derived for the former. Informed traders choose their strategy by trading off the adverse selection costs of the stock and options market. If they trade too aggressively in one market, the market maker in this market increases their trading cost by widening the spread, which makes it advantageous for them to shift to the other market. So the equilibrium strategy is a mixed strategy where they randomize their trading across both markets. When $S = B$, informed traders are conjectured to either sell the stock or buy the put and their strategy is:

$$X_S^{ss}(B) = \left\{ \begin{matrix} sell\ stock\ with\ probability\ \pi_B^{s0} \\ buy\ put\quad with\ probability\ 1-\pi_B^{s0} \end{matrix} \right\}$$

When $S = G$, they either buy the stock or sell the put and their conjectured strategy is:

$$X_S^{ss}(G) = \left\{ \begin{matrix} buy\ stock\ with\ probability\ \pi_G^{s0} \\ sell\ put\quad with\ probability\ 1-\pi_G^{s0} \end{matrix} \right\}$$

The zero profit bid and ask prices set by the stock and options market makers, conditional on the informed traders' conjectured trading strategies, are

$$B_S^{s0} = E(\tilde{v}\,\mathrm{I}stock\ sale) = \bar{v} - \frac{\alpha\pi_S^{so}(2\mu-1)(v_H - v_L)}{2\beta(1-\alpha) + 2\alpha\pi_B^{s0}}$$

$$A_S^{so} = E(\tilde{v}\,\mathrm{I}stock\ buy) = \bar{v} + \frac{\alpha\pi_G^{so}(2\mu-1)(v_H - v_L)}{2\beta(1-\alpha) + 2\alpha\pi_G^{s0}}$$

$$B_P^{s0} = E\left[(K-\tilde{v})^+\,\mathrm{I}put\ sale\right] = \frac{(K-v_L)\left[(1-\alpha)(1-\beta) + 2\alpha(1-\mu)\left(1-\pi_G^{s0}\right)\right]}{2(1-\alpha)(1-\beta) + 2\alpha\left(1-\pi_G^{s0}\right)}$$

$$A_P^{s0} = E\left[(K-\tilde{v})^+\,\mathrm{I}put\ buy\right] = \frac{(K-v_L)\left[(1-\alpha)(1-\beta) + 2\alpha\mu\left(1-\pi_B^{s0}\right)\right]}{2(1-\alpha)(1-\beta) + 2\alpha\left(1-\pi_B^{s0}\right)}$$

The equilibrium bid-ask spreads in the two markets are calculated as follows:

$$\Delta_S^{s0} = A_S^{s0} - B_S^{s0} = (2\mu-1)\left[\alpha(v_H - v_L) + (1-\alpha)(1-\beta)(v_H - K)\right]$$

$$\Delta_P^{s0} = A_P^{s0} - B_P^{s0} = (2\mu-1)\left[\alpha(K - v_L) - \beta(1-\alpha)(v_H - K)\right]$$

Given the informed traders' bias towards the stock rather than the option, it is not surprising that the stock market maker sets a wider spread than his option counterpart. Further more, the spread with stock market and that of the stock and options market reveals that the introduction of option trading leads to wider spreads in the underlying stock as the market maker in the stock faces an increased threat of informed trading.

In the next section, margin requirements are introduced. John *et al*. (2000) show that the trading intensity is no longer symmetric. This is because of the asymmetry in margin requirements between the stock and options market and also because options can only be sold, not bought, on margin. The economic intuition is, *ceteris paribus*, informed traders prefer to exploit their private information in the stock market rather than in the option market because of the former's greater information sensitivity. However, given the limited wealth, they prefer to trade in the market with the smaller margin requirements in order to increase their leverage and maximize their returns. When the leverage advantage and information sensitivity of the option relative to the stock is large, then it is more advantageous for the informed trader to trade option. With binding margin requirements, informed traders may no longer exhibit relative bias toward trading the stock. The implication of these arguments is that with margin requirements, informed traders may only trade the option in equilibrium if it provides substantially more leverage than the stock, which was not possible without margin requirement. It is also shown that option-listing shrinks (widens) the stock's bid-ask spread if margin requirements for the stock is large (small) and those for the option are small (large). Finally, with or without margin rules, it is shown that the introduction of option trading improves market efficiency.

John *et. al*. (2000) did not model the dynamic informational linkages between primary and derivative markets. Back (1993) takes a step in this direction. In an extension of the continuous time Kyle model, he introduced an option that is hypothetically redundant, in the sense that one could duplicate the cash flows to the option using the stock and a riskless asset. When the option is introduced as a traded asset, however, information flows through imperfectly correlated order flows in the stock and the option dynamically feeds back into the stock price process, causing volatilities to be stochastic. In other words, the introduction of the option as a traded asset into a model of adverse selection causes the option order flow to cease being informationally redundant with respect to the stock order flow, resulting in the stock and option prices being locally imperfectly correlated. This imperfect correlation renders the market incomplete, and a perfect hedge can no longer be formed.

2.1.2 Informational models of Volatility Discovery: Options Markets

The option market maker faces an adverse selection problem of facing differentially informed traders. Cherian and Jarrow (1996) develop two models where they show how the market maker, using Bayes Rule, sets bid and ask prices in order to compensate the loss of trading with informed traders. In Cherian and Jarrow's stylized setting, two types of informed traders interact with the relatively uninformed option market maker. So-called volatility traders have perfect information about the volatility but imperfect information about the underlying price movements.

Hence, they buy (sell) options when their estimate of the true volatility is above (bellow) the implied volatility obtained from the option's ask (bid) price. So-called directional traders have perfect information about the price movements of the underlying asset but imperfect information about the volatility. They buy (sell) options if their estimate of the option value, given their private information, is above (below) the quoted ask (bid) price. Unfortunately, option market makers cannot distinguish between volatility and directional traders. Instead, they make inferences about the probability of trading with either group from observed order flow in the options pit. These inferred probabilities are reflected in the market makers' bid-and ask-implied volatilities. They showed how these bid-and ask-implied volatilities are (theoretically) related to the true underlying volatility in the following results:

Result 1: If the volatility traders dominate the order flow, then the bid-and ask-implied volatilities (*IVB* and *IVA*, respectively) straddle the unconditional estimate of the true volatility (σ^*). Mathematically,

$$IVA > \sigma^* > IVB.$$

Result 2: If directional traders dominate the order flow, the bid-implied volatility (IVB) can exceed the unconditional estimate of the true underlying volatility (σ^*). Mathematically,

$$IVA > IVB > \sigma^*.$$

In a related paper, Cherian (1996) showed that the presence of traders with different types of information determines not only the position but also the size of the option's bid-ask spread. Specifically, the presence of directional traders is a signal to the market maker that volatility is likely to go up. Consequently, if the option market maker believes that directional traders are dominating the order flow (whether buying or selling), he or she will react by increasing both the bid-and ask-implied volatilities. Bid-ask spreads will decrease, and market liquidity will improve. In contrast, if market makers believe that volatility traders are buying, they may infer that volatility is likely to rise and, consequently, they will increase the ask-implied volatility. If they believe that volatility traders are selling, signaling a drop in volatility, then they will lower the bid-implied volatility. Combining these two results suggest that when volatility traders dominate the order flow, bid-ask spread will widen and markets will become less liquid. An adverse selection problem arises because market makers often unable to distinguish between volatility and directional trades.

The model focuses on the volatility formation and discovery process of two vega-max call options with different maturities. By allowing trade in two correlated securities, it is shown that the equilibrium strategy profile of the traders is a function of the parameters of the model and of strategic interaction. In the case with perfectly competitive traders, it is found that if the true volatility process is strongly mean reverting, traders who are informed on the second central moment of the underlying security (known as informed volatility traders) are more likely to pool their trades with traders who are informed on the first moment of the underlying security (called the informed μ-traders), with the pooling taking place in the nearer maturity options market. If, on the other hand, the true volatility process has a tendency of diverging from the long-run average, the μ-traders trade nearer maturity options while the volatility traders are driven to further maturities.

The wealth constraint makes them relatively indifferent to the behavior of volatility but extremely sensitive to the elasticity of the call option with respect to the stock price. When the true volatility process is neither mean reverting nor mean diverging in the strong sense, the volatility traders will either randomize their trades over the two markets, or buy in one market and sell in another. Imperfectly competitive volatility traders optimally follow mixed strategies. Cherian considers a two-period economy with two trading dates with a constant continuously compounded interest rate *r*. Trading are a stock, a riskless bond, and a European call option on a risky asset with fixed price, *K*, and expiration date, *T*. There are two classes of agents who trade options. They are (i) risk neutral, perfectly competitive market makers, who passively absorb the order flow imbalance, and (ii) a continuum, indexed by the interval [0,1], of variously informed, risk-neutral trades. The latter traders are further subdivided into three types: (a) the fraction $0<\alpha<1$ of volatility traders, σ-traders, (b) the fraction $0<\beta<1$ of directional or μ-traders, and (c) the fraction $0<1-\alpha-\beta<1$ of liquidity traders or hedgers. The volatility traders have information on the future volatility of the stock, the directional traders have information relating to the mean return of the stock, and the hedgers are uninformed traders who have price inelastic demand functions. Traders arrive sequentially and anonymously at the trading post to submit their demands to the market maker. Only one trader is assumed to be accommodated per period by the market maker. At the initial trading date, the stock price, S, is observed by all market participants. Market participants have the mutually absolutely continuous beliefs about the stock price evolution, thus ‘agreeing’ on the possible outcomes for the stock’s price at the next trading date, and at the option expiration date.

At trading date 1, there are three possible stock prices, S(1+u), S, and S(1+d) where $(1+u)>e^{r}>1>(1+d)$. The volatility of the stock’s return over the remaining life of the option can have two possible values: $\overline{\sigma}$ and $\underline{\sigma}$ where $\overline{\sigma}>\underline{\sigma}$. The state space is restricted to four possible outcomes. There are $(i)\ \{S(1+u),\overline{\sigma}\}$, $(ii)\ \{S,\overline{\sigma}\}$, $(iii)\ \{S(1+d),\overline{\sigma}\}$, *and* $(iv)\{S,\underline{\sigma}\}$. The choice of states (i)-(iii) correspond to a high volatility market at time 1 with changing stock prices (high, flat, or low). The final state corresponds to a low volatility and flat market. The market by construction is incomplete. Since there are four possible outcomes at time 1, the call option market is incomplete in the stock and bond over the first trading period. Secondly, as there are a continuum of stock prices possible at time T and only discrete trading allowed, the market is incomplete over the second trading period as well. To ensure that the stock price is fairly priced to uninformed participants, it is assumed that the expected return on the stock given current market-wide information equals the risk free return. More formally, at time 0,

$S = e^{-r}E(S_1)$, and at time 1, $S_1 = e^{-r(T-1)}E\left(S_T \mathrm{I} S_1, \sigma\right)$, where $(S_1,\sigma) \in \left\{\left\{S(1+u), \overline{\sigma}\right\}, \left\{S, \overline{\sigma}\right\}, \left\{S(1+d), \overline{\sigma}\right\}, \left\{S, \underline{\sigma}\right\}\right\}$. The informed traders will see trading opportunities in both the stock market and the option market. Given the partial equilibrium nature of the model, only the call option market equilibrium is characterized. The market maker sets option bid and ask prices contingent on the order submitted. At time 1, the state of nature is revealed to all market participants. Hence, all strategic trading and private information revelation, if any, takes place at time 0. Since there is no differential information at time 1, the call option's market price at time 1 can easily be determined using risk-neutral valuation. The time 0 information structures and action choices for the various market participants are as follows. It is an extensive form game with incomplete information. The market maker sets the bid and ask price given he observes the last transacted stock price S and conditional on the order submitted. The nature chooses according to the probabilities assigned for each state. The σ-traders observe $\overline{\sigma}$ and $\underline{\sigma}$. They cannot, however, distinguish if S(1+u), S, or S(1+d) occurs when volatility is high. In the case that the volatility is low, they know that S occurs. The μ-traders observe S(1+u), S, or S(1+d). In the case of S, they do not know if $\overline{\sigma}$ or $\underline{\sigma}$ occurs. Otherwise they know that volatility is high. The information structure is consistent with σ-traders knowing the volatilities, but not the direction of stock price movements. Conversely, the μ-traders know the direction of the stock price movements, but not the volatilities. The σ-and μ-traders see the bid and ask prices and decide to either buy, sell, or refrain from trading. The hedgers are equally likely to buy or sell the call option irrespective of advertised prices. At time 1, since uncertainty about (S_1, σ) is resolved and all traders are risk-neutral, the call option is given by its discounted expected value at its maturity date. More formally,

$$C_1(S_1,\sigma) = S_1 N\left(h(S_1,\sigma)\right) - Ke^{-rT} N\left(h\left((S_1,\sigma)\right) - \sigma\sqrt{T}\right)$$

$$and\ h(S_1,\sigma) = \frac{\log\left(S_1 \big/ Ke^{-rT}\right)}{\sigma\sqrt{T}} + \frac{1}{2}\sigma\sqrt{T}$$

where N(.) denotes the cumulative normal distribution function of the standard normal random variable $h(S_1, \sigma)$. Given the equilibrium call prices at time 1, the call market equilibrium at time 0 can be derived. The informed trader's optimality conditions given he observes the ask price, A, and the bid price, B, are:

Buy if and only if A < $e^{-r}E(C_1(S_1,\sigma)$ I Information set) $\leq A$, and
Sell if and only if < $e^{-r}E(C_1(S_1,\sigma)$ I Information set) < B.

Hence the σ-trader and μ-trader buys if his valuation exceeds the ask price, sells if his valuation is less than the bid price, and refrains from trading otherwise. The hedgers, by virtue of their price inelastic demand functions, are not strategic and trade regardless of the actions of the informed traders. The market makers forms posterior beliefs about the state (S_1, σ) based on the order submitted and his rational conjectures over who is trading. Given that the market maker is risk neutral and perfectly competitive, he sets bid and ask prices as follows:

$$A = e^{-r}E(C_1(S_1\ \sigma) \text{ I Buy})$$

And

$$B = e^{-r}E(C_1(S_1\ \sigma) \text{ I Sell})$$

Where $C_1(S_1\ \sigma)$ are Black-Scholes/Merton values, both the bid and ask prices are weighted averages of Black-Scholes/Merton values.

In order to study the informational content of implied volatilities, Cherian removes the deterministic biases that Black-Scholes/Merton formula sets forth due to nonlinearities. Cherian defines an option is said to be *vega-max* if the second derivative of the option with respect to the stock price volatility is zero. For vega-max options, *implied volatilities are rational forecast of true volatility and the bid ask can be written as:* $a \approx e^{-r}E[(\tilde{\sigma})$ I *Buy]*
$b \approx e^{-r}E[(\tilde{\sigma})$ I Sel)]

where a and b are the bid and ask implied volatilities which set the option ask and bid prices equal to Black-Scholes/Merton prices respectively. Define the unconditional expectation and variance of volatility as σ** and Φ^2, respectively. Hence $\sigma^{**} = \delta\overline{\sigma} + (1-\delta)\underline{\sigma}$, and

$\Phi^2 = \delta(1-\delta)\left[\overline{\sigma} - \underline{\sigma}\right]^2$. Calculating the appropriate conditional probabilities in a Bayesian manner, the initial ask and bid implied volatilities are given by

$$\begin{aligned}
a &= e^{-r}\left(\sigma^{**} + \frac{\Phi^2}{\left[\overline{\sigma} - \underline{\sigma}\right]}\left[\frac{\alpha + 1/3\beta}{1/2(1-\alpha) + \delta\alpha - 1/3\beta(1-\delta)}\right]\right) \\
b &= e^{-r}\left(\sigma^{**} - \frac{\Phi^2}{\left[\overline{\sigma} - \underline{\sigma}\right]}\left[\frac{\alpha - 1/3\beta}{1/2(1-\alpha) + (1-\delta)\alpha - 1/3\beta(1-\delta)}\right]\right)
\end{aligned}.$$

The difference between the bid and ask volatilities is defined as spread. The higher the spread, the less liquid the market is. Two traded vega-max European call options are considered on the risky security with different maturities. Cherian studies how volatility traders interact with μ-traders in the presence of adverse selection, given a Bayesian market maker who passively addresses the order flow imbalance in two correlated securities. This game of incomplete information is modeled in a Bayesian equilibrium framework. The two options have the same strike, K, but different expiration dates, T_1 and T_2, with $T_1<T_2$. The prior beliefs on asset volatility is captured by a 2-point distribution, {δ, 1-δ} on the random value of the underlying security's volatility. The nearer maturity option has the volatility tuple $\left\{\overline{\sigma_1}, \underline{\sigma_1}\right\}$ while the further maturity one has the tuple $\left\{\overline{\sigma_2}, \underline{\sigma_2}\right\}$. These tuple need not be identical, as the volatility, which goes to Black-Scholes/Merton formula, should equal that which prevails over the remaining life of the option. Market orders to buy or sell options 1 or 2 still arrive in a sequential manner at the trading post. The uninformed traders buy or sell options 1 or 2 with equal probability. The informed volatility traders trade optimally and strategically, i.e., they are allowed pure or mixed trading strategies. Let the trading strategy of the informed volatility traders be represented by a 2-point distribution {π, 1-π} over his purchase of option 1 and option 2 respectively when the true volatility is high and a 2-point distribution {ν, 1-ν} over his sale of option 1 and option 2 respectively when the true volatility is low. Let the trading strategy of the informed μ-traders be represented by a 2-point distribution {θ, 1-θ} over his trade in option 1 and option 2 respectively. Let $\delta_j(\pi,\theta)$ for j = 1,2 be the market maker's posterior probability of the set $\left\{s : \sigma_j = \overline{\sigma_j}\right\}$ given the market order to buy and informed's

optimal strategies. Similarly, let $\delta_j(\nu,\theta)$ for j = 1,2 be the market maker's posterior probability of the set $\{s : \sigma_j = \underline{\sigma_j}\}$ given the market order to sell and the informed's strategies. The market maker sets ask and bid volatilities as follows

$$\begin{aligned}
a_j(\pi,\theta) &= \delta_j(\pi,\theta)\overline{\sigma_j} + \left(1-\delta_j(\pi,\theta)\right)\underline{\sigma_j} \\
b_j(\upsilon,\theta) &= \delta_j(\upsilon,\theta)\overline{\sigma_j} + \left(1-\delta_j(\upsilon,\theta)\right)\underline{\sigma_j}
\end{aligned}$$

The informed volatility trader's optimal trading strategy (π,ν) given the market maker's ask and bid volatilities and the fact that he maximizes his expected trading profits is given by

$$\begin{aligned}
\pi &\in \arg\max_{\{x\}}\left[x.\frac{\partial BS\left(\overline{\sigma_1}\right)}{\partial\sigma}\left(\overline{\sigma_1}-a_1(\pi,\theta)\right)+(1-x).\frac{\partial BS\left(\overline{\sigma_2}\right)}{\partial\sigma}\left(\overline{\sigma_2}-a_2(\pi,\theta)\right)\right] \\
\upsilon &\in \arg\max_{\{x\}}\left[x.\frac{\partial BS\left(\underline{\sigma_1}\right)}{\partial\sigma}\left(b_1(\upsilon,\theta)-\underline{\sigma_1}\right)+(1-x).\frac{\partial BS\left(\underline{\sigma_2}\right)}{\partial\sigma}\left(b_2(\upsilon,\theta)-\underline{\sigma_2}\right)\right]
\end{aligned}$$

Cherian shows that in the presence of a wealth constraint, the μ-traders trade only in the nearer maturity option i.e., the one which expires at date 1 in order to maximize their expected profit. The equilibrium behavior of the volatility traders is more complicated. They can be either in the nearer maturity or further maturity option, or randomize over the two markets. In order for the trading strategies to be optimal, it must be the case that

$$\begin{aligned}
&\left[\pi.\frac{\partial BS\left(\overline{\sigma_1}\right)}{\partial\sigma}\left(\overline{\sigma_1}-a_1(\pi,\theta)\right)+(1-\pi).\frac{\partial BS\left(\overline{\sigma_2}\right)}{\partial\sigma}\left(\overline{\sigma_2}-a_2(\pi,\theta)\right)\right] \geq \\
&\left[x.\frac{\partial BS\left(\overline{\sigma_1}\right)}{\partial\sigma}\left(\overline{\sigma_1}-a_1(\pi,\theta)\right)+(1-x).\frac{\partial BS\left(\overline{\sigma_2}\right)}{\partial\sigma}\left(\overline{\sigma_2}-a_2(\pi,\theta)\right)\right] \\
&\textit{and} \\
&\left[\upsilon.\frac{\partial BS\left(\underline{\sigma_1}\right)}{\partial\sigma}\left(b_1(\upsilon,\theta)-\underline{\sigma_1}\right)+(1-\upsilon).\frac{\partial BS\left(\underline{\sigma_2}\right)}{\partial\sigma}\left(b_2(\upsilon,\theta)-\underline{\sigma_2}\right)\right] \geq \\
&\left[x.\frac{\partial BS\left(\underline{\sigma_1}\right)}{\partial\sigma}\left(b_1(\upsilon,\theta)-\underline{\sigma_1}\right)+(1-x).\frac{\partial BS\left(\underline{\sigma_2}\right)}{\partial\sigma}\left(b_2(\upsilon,\theta)-\underline{\sigma_2}\right)\right]
\end{aligned}$$

After substituting for $a_j(\pi,\theta)$ and $b_j(\nu,\theta)$and simplification, their optimal trading strategies have to satisfy

$$(\pi - x)\left[(1-\delta_1(\pi,\theta))(\overline{\sigma_1}-\underline{\sigma_1})\bullet\frac{\partial BS(\overline{\sigma_1})}{\partial\sigma}-(1-\delta_2(\pi,\theta))((\overline{\sigma_1}-\underline{\sigma_1}))\frac{\partial BS(\overline{\sigma_2})}{\partial\sigma}\right]\geq 0,\ \textit{and}$$

$$(\upsilon - x)\left[(\delta_1(\upsilon,\theta))(\overline{\sigma_1}-\underline{\sigma_1})\bullet\frac{\partial BS(\overline{\sigma_1})}{\partial\sigma}-(\delta_2(\upsilon,\theta))((\overline{\sigma_1}-\underline{\sigma_1}))\frac{\partial BS(\overline{\sigma_2})}{\partial\sigma}\right]\geq 0.$$

Under the pure strategy, the volatility informed trader buys the nearer maturity option if his expected profit trading the nearer maturity option is strictly greater than trading the further maturity one. The necessary and sufficient condition is derived by setting π=1 as

$$\frac{(\overline{\sigma_1}-\underline{\sigma_1})\sqrt{T_1}}{(\overline{\sigma_2}-\underline{\sigma_2})\sqrt{T_2}\,e^{-r(T_2-T_1))}}>1+\frac{4\delta(\alpha+1/3\beta)}{1-\alpha-\beta},$$

$$\textit{where, }\frac{\partial BS(\overline{\sigma_j})}{\sigma}=Ke^{-rT_j}\sqrt{T_j/2\Pi} \tag{I}$$

A similar condition holds for the sell side for a volatility informed trader. The necessary and sufficient condition is derived by setting ν=1 as

$$\frac{(\overline{\sigma_1}-\underline{\sigma_1})\sqrt{T_1}}{(\overline{\sigma_2}-\underline{\sigma_2})\sqrt{T_2}\,e^{-r(T_2-T_1))}}>1+\frac{(1-\delta)(\alpha-1/3\beta)}{1/3\beta+1/4(1-\alpha-\beta)},. \tag{II}$$

The market maker's ask and bid volatilities in the case when the volatility trader chooses the nearer maturity option are given by solving for $a_j(\pi,\theta)$ and $b_j(\nu,\theta)$ at (π,ν,θ) = (1,1,1).

Alternatively, the volatility trader buys a further maturity option if his expected profit is strictly greater than trading the nearer maturity option. The necessary and sufficient condition is derived by setting π=0 as

$$\frac{\left(\overline{\sigma_1}-\underline{\sigma_1}\right)\sqrt{T_1}}{\left(\overline{\sigma_2}-\underline{\sigma_2}\right)\sqrt{T_2}\,e^{-r(T_2-T_1))}}<1+\frac{\delta\left(1/3\beta-\alpha\right)}{\alpha\delta+1/4(1-\alpha-\beta)}, \qquad \text{(III)}$$

and the necessary and sufficient condition for selling further maturity option is derived by setting ν=0 as

$$\frac{\left(\overline{\sigma_1}-\underline{\sigma_1}\right)\sqrt{T_1}}{\left(\overline{\sigma_2}-\underline{\sigma_2}\right)\sqrt{T_2}\,e^{-r(T_2-T_1))}}<1+\frac{1/4(1-\alpha-\beta)}{\alpha\left(1-\delta\right)+1/4(1-\alpha-\beta)}. \qquad \text{(IV)}$$

The market maker's ask and bid volatilities are given by solving for $a_j(\pi,\theta)$ and $b_j(\nu,\theta)$ at (π,ν,θ) = (0,0,1). In short, since the μ-trader optimally trades the nearer maturity options under all conditions, there exists a Bayesian equilibrium in which the volatility trader is driven to the market with no μ-trader if conditions (III) and (IV) prevail, and trades in the market which the μ-trader dominates when conditions (I) and (II) are satisfied.

Under the mixed strategy, the volatility trader randomize their trades in the two options markets, i.e., given the state of nature, if both the market conditions for pure strategies are violated, the volatility traders follow mixed strategies. In order for mixed strategies to be optimal, it must be the case that the volatility traders are indifferent between trading nearer and further maturity options. For a volatility trader, this requires that

$$\frac{\partial BS\left(\overline{\sigma_1}\right)}{\partial\sigma}\bullet\left(1-\delta_1(\pi,1)\right)\left(\overline{\sigma_1}-\underline{\sigma_1}\right)=\frac{\partial BS\left(\overline{\sigma_2}\right)}{\partial\sigma}\bullet\left(1-\delta_2(\pi,1)\right)\left(\overline{\sigma_2}-\underline{\sigma_2}\right).$$

Under this condition there exists Bayesian equilibrium in mixed strategies for the volatility traders when they are informed that volatility is high or volatility is low. Under imperfect competition, the new optimal trading strategy, (π,ν) for the volatility traders is characterized by

$$\pi \in \arg\max_{\{x\}}\left[x.\frac{\partial BS\left(\overline{\sigma}_1\right)}{\partial \sigma}\left(\overline{\sigma}_1 - a_1(x,\theta)\right) + (1-x).\frac{\partial BS\left(\overline{\sigma}_2\right)}{\partial \sigma}\left(\overline{\sigma}_2 - a_2(x,\theta)\right)\right]$$

$$\upsilon \in \arg\max_{\{x\}}\left[x.\frac{\partial BS\left(\underline{\sigma}_1\right)}{\partial \sigma}\left(b_1(x,\theta) - \underline{\sigma}_1\right) + (1-x).\frac{\partial BS\left(\underline{\sigma}_2\right)}{\partial \sigma}\left(b_2(x,\theta) - \underline{\sigma}_2\right)\right]$$

and there exists a non-empty subset of parameters for which the Bayesian equilibrium in mixed trading strategies for imperfectly competitive volatility traders is unique. In fact, when volatility is high and

$$\left(1+\frac{\delta(\alpha-1/3\beta)}{1/3\beta\delta+1/4(1-\alpha-\beta)}\right)\left(1+\frac{\delta(\alpha+1/3\beta)}{1/4(1-\alpha-\beta)}\right)^2 \geq k \geq 1+\frac{\delta(1/3\beta-\alpha)}{\alpha\delta+1/4(1-\alpha-\beta)},$$

the unique equilibrium in mixed strategies is to buy options. Similarly, when volatility is low and $k_{low} \leq k \leq k_{high}$ the unique equilibrium in mixed strategies is to sell options. Where,

$$k \equiv \frac{\left(\overline{\sigma}_1 - \underline{\sigma}_1\right)\sqrt{T_1}}{\left(\overline{\sigma}_2 - \underline{\sigma}_2\right)\sqrt{T_2 e^{-r(T_2-T_1)}}}, \quad k_{low} = \frac{1/4(1-\alpha-\beta)[\alpha(1-\delta)+1/4(1-\alpha-\beta)]\delta}{[1/3\beta\delta+1/4(1-\alpha-\beta)][1/3\beta+1/4(1-\alpha-\beta)]},$$

$$k_{high} = \frac{[(1/3\beta-\alpha)\delta+\alpha+1/4(1-\alpha-\beta)]^2[\alpha(1-\delta)+1/4(1-\alpha-\beta)]\delta}{[1/3\beta\delta+1/4(1-\alpha-\beta)][1/3\beta+1/4(1-\alpha-\beta)]1/4(1-\alpha-\beta)}$$

Cherian also shows that with certain parameter restrictions, the volatility trader who is wealth-constrained switches from mixed strategies to trading purely in further maturity options, whereas he switches more slowly when he is not wealth-constrained. The volatility trader who is wealth-constrained is more sensitive to the elasticity of the option with respect to volatility than one who is not wealth- constrained, whereas a volatility trader who is not wealth-constrained is more sensitive to the mean reverting behavior of volatilities.

Cherian and Vila (1997) in a simple but realistic model of option market making show how information on future price volatility is incorporated in prices and how liquidity in option markets is affected by information trading. In this context, they explain how the bid-ask spread introduces a bias into transaction prices that affects estimate of the true underlying volatility, based on implied volatilities. The model is designed in the spirit of Cherian (1996) and Cherian and Jarrow (1996). They consider a two-period economy with two trading dates, denoted by $t = 0$, and $t = 1$, and a constant, continuously compounded interest rate, r. Trading are a stock, a riskless bond, and a European call option on a risky asset with a fixed strike, K, and expiration date T.

Two classes of agents trade options: risk neutral, perfectly competitive market makers, who passively absorb the order flow imbalance, and a continuum, indexed by interval [0,1], of variously informed risk neutral traders. The latter traders are further subdivided into three types: (1) the fraction $0<\alpha<1$ of volatility traders, or σ-traders, (2) the fraction $0<\beta<1$ of directional traders, or μ-traders, and (3) the fraction $0<1-\alpha-\beta<1$ of liquidity traders, or hedgers. The volatility traders have information about future volatility of the stock; the directional traders have information relating to the mean return of the stock; and the hedgers are uninformed traders with price-inelastic demand functions.

Traders arrive sequentially and anonymously at the trading post to submit their demands to the market maker. In the spirit of traditional option-pricing models, the stock price evolution over time is taken as given. The market by construct is incomplete at time t=1, because four outcomes are possible at time t=1, the call option market is incomplete in the stock and bond over the first trading period. Also because a continuum of stock prices is possible at time T and only discrete trading is allowed, the market is also incomplete over the second trading period. To ensure the stock is fairly priced to uninformed participants, the expected return on the stock given current market wide information equals the risk-free return.

The informed traders, therefore, will see trading opportunities in both the stock and option market. Given the partial equilibrium nature of the model, only the call option market equilibrium is characterized. The trading mechanism at each date is one in which market maker sets option bid and ask prices contingent on the order submitted. The equilibrium characterization in this economy is similar to the one used in the Cherian (1996) and Cherian and Jarrow (1996). At time 1, because uncertainty about (S_1, σ) is resolved and all traders are risk neutral, the call option is given by its discounted expected value at its maturity date. Denoting $C_1(S_1, \sigma)$ as the call price at time 1,

$$C_1(S_1, \sigma)=BS(S_1, \sigma) ,$$

$$BS(S_1,\sigma)=S_1 N\left[h(S_1,\sigma)\right]-Ke^{-rT}N\left[h(S_1,\sigma)-\sigma\sqrt{T}\right],$$

Where $h(S_1,\sigma)=\dfrac{\log\left(\dfrac{S_1}{Ke^{-rT}}\right)}{\sigma\sqrt{T}}+1/2\sigma\sqrt{T}$, *and*

$$(S_1,\sigma)\in\left[\left(S(1+u),\overline{\sigma}\right),\left(S,\overline{\sigma}\right),\left(S(1+d),\overline{\sigma}\right),\left(S,\underline{\sigma}\right)\right]$$

And $N(.)$ = the cumulative distribution function of the standard normal random variable. Given the equilibrium call prices at time 1, we can derive the call market equilibrium at time 0. The set of optimal strategies for the three strategic traders (i.e., the market maker and the two differentially informed traders) must be derived first. The informed traders optimal conditions, given that they observe the ask price, *A*, and the bid price, *B*, are

$$\begin{aligned}&\textit{buy}\quad \textit{iff}\ \ A<e^{-r}E\left[C_1(S_1,\sigma)\mid \textit{Information set}\right],\\&\textit{no trade iff}\ \ B\le e^{-r}E\left[C_1(S_1,\sigma)\mid \textit{Information set}\right]\le A,\ \textit{and}\\&\textit{sell}\quad \textit{iff}\ \ e^{-r}E\left[C_1(S_1,\sigma)\mid \textit{Information set}\right]<B.\end{aligned}$$

Hence, the informed σ-trader and μ-trader will buy if their valuations exceed the ask price, sell if their valuations are less than the bid price, and refrain from trading otherwise. Market makers form posterior beliefs about the states (S_1,σ) based on the order submitted and rational conjectures about who is trading. Given the market makers are risk neutral and perfectly competitive, they set bid and ask prices as follows:

$$A=e^{-r}E\left[C_1(S_1,\sigma)\mid Buy\right]=e^{-r}\left(\sigma^{**}+\frac{\Phi^2}{(\overline{\sigma}-\underline{\sigma})}\left[\frac{\alpha+1/3\beta}{1/2(1-\alpha)+\alpha\delta-1/3\beta(1-\delta)}\right]\right),$$

$$B=e^{-r}E\left[C_1(S_1,\sigma)\mid Sell\right]=e^{-r}\left(\sigma^{**}-\frac{\Phi^2}{(\overline{\sigma}-\underline{\sigma})}\left[\frac{\alpha-1/3\beta}{1/2(1-\alpha)+\alpha(1-\delta)-1/3\beta(1-\delta)}\right]\right)$$

$$\textit{where}\quad \sigma^{**}=\delta\overline{\sigma}+(1-\delta)\underline{\sigma},\quad \textit{and}\ \Phi^2=\delta(1-\delta)(\overline{\sigma}-\underline{\sigma})^2.$$

In this equilibrium set up, σ^{**} and Φ^2 are defined as the unconditional expectation and variance of volatility. This equilibrium bid and ask will have a spread that rationally reflects the information component of the underlying price and its volatility. The author attempted to verify empirically the theoretical model of the microstructure of option markets. The main finding was that the presence of volatility traders tends to widen the bid-ask spread in options and the presence of directional traders has the opposite effect. This phenomenon is explained mainly by the fact that the presence of volatility traders is a signal that a subset of the informed traders' assessment of volatility is different from the market's assessment, thus endogenously creating and adverse-selection-type cost reflected through widening spread. The presence of directional traders has an opposite effect because they create upward biases in volatility, thus diminishing spreads.

2.1.3 Other Theoretical Information Models: Options Markets

Biais and Hillion's (1990) develop a pioneering study of price formation in an option market with two call options different strikes under two states of nature. In their model, a perfectly competitive Bayesian market maker who faces the possibility of trading with an informed trader with quantity constraints uses risk and information adjusted posterior probabilities when calculating bid and ask prices. An interesting result is that when market makers are risk neutral, the insider optimally trades in-the-money options. This finding is contrary to the predictions of traditional option-pricing theory, which claims that because of the high degree of leverage provided by out-of-the-money options, insiders should concentrate their trades in these instruments. The rationale for the latter strategy is that insiders obtain maximal "bang for the buck" by trading on their own private information.

Kraus and Smith (1996) present situations in which introducing an option significantly affects the price process of the underlying asset despite the fact that, in both cases, the available assets without the option appear to span the payoff space. In both situations, they consider a model with two rounds of trading. In the first case, there are two types of investors, distinguished by their private information about final payoffs. At the initial trading date, the equilibrium without the option is such that the two available securities appear to each investor to offer a dynamically complete market. The two types of investors, however, partly disagree on which two values of future price may take on, but neither type knows the other's beliefs exactly. Thus each investor sees the stock price next period as having a binomial distribution, so a portfolio of stock and the riskless asset can replicate the option, but the different groups believe in different binomial distributions. Since, the option is a bet on the future stock price, the price of the option conveys information to each investor type about the beliefs of the other type, and thus about the other type's private information that is not conveyed by the stock price alone. The ability to trade a derivative security introduces a new, and potentially important dimension. At the same time information flows may differ in markets, leading to divergences in market prices and introducing the possibility of arbitrage between markets.

If derivative markets affect security market liquidity, then it is important to determine how much effects arise and what they imply for price behavior. The issue of market liquidity and index futures is addressed by Subrahmanyam (1991). His model determines where traders choose to trade given the ability to trade both individual securities and a basket of securities. He examines the informed traders’ demand for the basket security, assuming a given level of liquidity trades in each security and that the market maker does not observe the order flow in other markets. One equilibrium in his model is that all discretionary traders transact in the basket. If, however, there is large nondiscretionary liquidity trade in the individual securities, then this greater liquidity may dominate the diversification effect, with the result that in equilibrium all discretionary traders transact securities. Moreover, an equilibrium in which some discretionary traders transact in the basket while others trade individual securities cannot be ruled out. Consequently, in his model, any equilibrium may prevail. Subrahmanyam argues that the more reasonable equilibrium involve concentration, with either all discretionary traders transacting in the basket or in the individual securities.

2.1.4 Other Theoretical Information Models: Futures Markets

The existence of price gaps between markets and their implications for market behavior has been considered in related work by Kumar and Seppi (1990). Kumar and Seppi (1990) analyze a model of a security market and a futures market trading index futures on the securities. Information flows differ between markets, and there is a lag of observing the prices in the other market. This lag could arise from timing differences or frictions in transmitting information, but it is assumed existence is important for the model. Information differences are introduced by assuming that floor traders in futures markets have information about the level of the index, while specialists have information about the value of the individual stocks in the index. These two price-setting agents are assumed to use Bayesian updating in calculating the conditional expected value for their respective securities. Their information sets include their own signal, the history of prices in their own market, and the history of prices in the other markets with a certain lag period. This lag dictates that market makers in the two markets do not have identical information, and this provides the basis of prices in the markets differs. Consequently, short-term price discrepancies can arise, leading to arbitrage possibilities in the two markets.

Holden (1995) explains the existence of arbitrage between stocks and futures in an equilibrium model as arising from the risk aversion of the market makers and independent liquidity shocks to futures and stock markets. In Fremault (1991), different traders have unequal access to stock and futures markets. In her model, only arbitrageurs have access to all markets.

The role of arbitrageurs is mainly based on reallocating risk, although she also briefly considers informational issues. Chen, Cuny, and Haugen (1995) have presented an equilibrium model of stock index futures basis behavior, where futures contracts are not perfect substitutes for stocks because they lack customization value of stock portfolios. In their model when market volatility increases, current stockholders sell futures to hedge against the increasing risk of their customized stock portfolios decreasing the basis. As a result of increased hedging the futures open interest increases too.

Chan (1993) also models the feature of imperfect informational integration between different markets. He models the observed cross-autocorrelation between different stocks with market makers, who price individual stocks based on signals pertaining to that specific stock without access to information in other markets. Stock returns become positively cross-autocorrelated when market makers update their prices after having seen the previous price information in other markets.

Heitala *et al*. (2000) present a model based on short sales constraints and informational lags between different markets. In their model stocks and futures are perfect substitutes, except that short sales are only in the futures markets. The futures price is more informative than the stock price, because the existence of short sales constraints in the stock market prohibits trading in some states of the world. If an informed trader with no initial endowment in stocks gets a negative signal about the common future value of stocks and futures, she is only able to sell futures. In addition uninformed traders also face short sales constraint in the stock market. These constraints can be binding irrespective of the information that the informed traders possess. As a result, the stock price is less informative than the future price even if the informed trader has received positive information about the common value of the securities, because uninformed traders might not be able to trade. According to their model, stocks can be under and over priced compared to futures, provided that market makers in stock and futures market only observe with a lag in prices in the other market. The model implies that 1.) the basis is positively associated with the contemporaneous futures returns, 2.) the basis is negatively related with contemporaneous stock returns, 3.) futures returns lead the stock returns, 4.) stock returns also lead futures returns, but to a lesser extent and 5.) the trading volume in the stock market is positively associated with contemporaneous stock return. The model is tested using daily data from the Finish index futures markets.

3. The Survey of the Empirical Literature: Derivatives Markets

It has been well established in the current literature that the option markets play an important role in impounding information into security prices (Black, 1975; Anthony, 1978; Chiras and Manaster, 1978; Manaster and Rendleman (1982). Black (1975) first suggested that the higher leverage available in options markets might induce informed traders to transact options rather than stocks and hence the option market may lead the stock market in revealing information first.

Chiras and Manaster (1978) attempt to determine the informational content of observed stock options prices. In their study, it is observed that prices observed from different options on the same stock result in different calculated implied standard deviations. If the option model is correct and the true standard deviation of a stock’s return is unique, the presence of a multiple implied standard deviations implies that the observed option prices are not in equilibrium. This hypothesis is tested by attempting to identify ‘overpriced’ and ‘underpriced’ options. It is concluded that, contrary to the efficient market hypothesis, ‘underpriced’ and ‘overpriced’ options can be identified from currently available information. A trading rule, which, in theory, is risk free but earns substantially greater than the risk free rate is presented and test results are significant. An amended version of Black and Scholes (1973) option pricing model, adjusted for dividend payments, is used in the paper. An estimate of each stock’s return variance is derived from current market conditions instead of from historical data. Tests indicate that the market-derived estimates of variance are superior to those based only on historical data. A method is introduced for calculating a collective assessment of volatility at any point in time, which more properly accounts for the informational value of each implied standard deviation. The changes in the predictive characteristics of option prices over time are examined. A test of the hypothesis that standard deviations inferred from option prices have been better predictors of standard deviations of future stock returns than standard deviations obtained from historical stock returns is found statistically significant implying that the options market is a venue for information.

The sample contains 23 monthly observation periods beginning June 1973 and ending April 1975. Data are recorded for the last trading day of each month for each option on stocks whose options were traded on the Chicago Board of Options Exchange (CBOE) as of June 29, 1973. If one accepts the assumptions of the option model and also believes that the option market is efficient then he will expect all options on the same stock at a given time to have identical ISD values. However, the ISD values are found to differ widely.

Manaster and Rendleman (1982) use the Black and Scholes’ options pricing model and use options prices as predictors of the equilibrium stock prices. Implied stock prices and implied standard deviations are calculated jointly from options prices and then the implied stock prices are compared with observed stock prices. The comparison reveals that the implied prices contain information regarding equilibrium stock price that is not fully reflected in observed stock prices. They reject the hypothesis that implied stock prices provide no information regarding the future movements of observed stock prices. The time horizon for information effect is one day only. This conclusion is based on two different tests: one an *ex- post* test and the other an *ex- ante* test. In both tests, stock portfolios are formed based on the differences between implied and observed prices and compare the returns earned on the various portfolios. In the *ex-post* test, information contained in closing stock prices and option prices are employed to form the portfolios and unrealistically assume that a trader could simultaneously process the information and trade the stocks at closing prices. The *ex-ante* tests are similar to the *ex-post* tests except that the simulated stock purchases are made at the following days' closing prices. Although the results of the ex-ante tests still allow rejecting the hypothesis that implied stock prices contain no information about future stock returns, they are not as significant. Price data are taken from the CRSP options tapes, which contain daily closing prices and maturity dates for all options, which traded on listed options exchanges from 26 April 1973 to 30 June 1976.

There are 805 trading days over the period and 172 stocks with listed options. In addition to the options data, the CRSP tapes also contain information on the prices and returns of the underlying stocks. The stock information is taken from the CRSP's daily stock master tape and includes stock price and return data as well as a complete dividend history of each stock. The risk free interest rate is collected weekly and is measured by the yield on 91 day U.S. T-bills. Options that have the potential for optimal premature exercise are deleted from the sample. An option is excluded on any day from which the present value of the dividends to be paid over the remaining life of the option exceeds the present value of the interest foregone by early exercise. A modified version of Black and Scholes (1973) option pricing formula adjusted for dividend payments is used to estimate implied stock price and implied volatility simultaneously using data from several options on the same stock. The results of this study show that the closing prices of listed call options contain information about equilibrium stock prices that is not contained in the closing prices of the underlying stocks.

They offer two potential explanations for this finding. The simplest explanation is that closing option and stock transactions do not always take place at the same time. Therefore, it is possible that additional information contained in closing option prices merely reflects more recent rather than better information. The alternative explanation is that closing option prices reflect fundamental information about the equilibrium values of underlying stocks that is not contained in closing stock prices.

Bhattacharya (1987) addresses the issue of speed at which new information is reflected in related security markets. Specifically, he examines price revisions in option and stock markets to test the hypothesis that option prices contain no additional information as compared to the contemporaneous stock prices. The basic approach, using options transaction by transaction data and nearly contemporaneous stock price data, is to assume that call options are priced in the market according to the Black and Scholes' (1973) option pricing model.

Then, given the observed prices of a pair call options identical in all respects except their exercise prices, the Black and Scholes model is inverted to obtain the implied stock value. This is compared to the contemporary observed stock price. He uses transaction data to examine the intraday lead/lag relation between markets. He has observed bid/ask call prices to compute implied bid/ask stock prices, which are, in turn, compared to actual bid/ask stock prices to identify arbitrage opportunities. The stock is considered underpriced (overpriced) if the implied bid (ask) is higher (lower) than the actual ask (bid). His test results indicate that option prices do seem to contain information not reflected in contemporaneous stock prices. A simulated trading strategy based on these arbitrage signals indicates that profits insufficient to overcome transaction costs for all intraday holding periods. Bhattacharya, however, confirms, the Manaster and Rendleman (1982) trading strategy results by documenting statistically significant excess returns for overnight holding periods.

A critical aspect of Bhattacharya's test design is that it will only detect whether the option market leads the stock market and the vice versa. He recognizes the problem but does not perform the simulations in the reverse way. In order to test for the possibility of stock prices leading option prices he would have had to use observed bid/ask stock prices to compute implied bid/ask call prices to identify over(under)-pricing. Although he shows that option price changes have some predictive power, his results do not preclude the possibility that the stock price changes predict option price changes.

Anthony (1988) investigates the relation between common stock and call option trading volumes. He assumes that individuals are motivated to prefer option-information trading. One should expect to observe an information asymmetry between the option and share markets. Following a Jennings *et al* (1981) sequential information flow model, option-volume increases should precede volume increases in the share market, surrounding information releases. In this sense, option trading leads trading in common shares.

Tests performed are derived from econometric procedures developed by Granger (1969) and Sims (1972). A sample of 25 firms is included in the study. The research investigates comparative behavior of listed call options and their underlying common shares for the period from January 1, 1982-June 30, 1983. Data collected include daily-volume information on the common shares. Volume data are also collected for all listed call options of sample firms that are actively traded during the sample period. The analyses in this paper are designed to detect firm-specific information flows. Therefore, raw volume data were first transformed to eliminate market effects by applying market model volume regressions. The first method employed is derived from Granger (1969), and Granger and Newbold (1977) and attempts to identify bivariate series directly through analyses of cross-correlograms or cross-covariances. In order to avoid spurious correlations, two univariate series are identified and then combined into multiple-series models for implementation of causality tests.

The model derived for the volume series are comparable to volume models obtained by Rogalski (1978) in an investigation of monthly stock and warrant data. Parameter estimates indicate a positive relation between adjacent daily volumes for both stocks and options, consistent with Rogalski’s findings. Daily trading volume in both series is positively correlated with succeeding day’s activity. His results indicate that addition of past stock-volume information significantly affects option-volume predictions and option volume is a causal variable for stock volume. He finds that option volume causes stock volume for thirteen firms, stock volume causes option volume for four firms, there is evidence of feedback for five firms, and no causal interpretation is possible for the remaining firms. Based on the one tailed test results, option trading in call options leads trading in the underlying stocks with one-day lag in thirteen of the twenty-five cases, while stock trading leads in only two cases although he tested for six days lags.

Stephan and Whaley (1990) investigate empirically the intraday price changes and trading volume relations between stocks and options for a sample of firms whose options are actively traded on the Chicago Board of Options Exchange (CBOE) during the first quarter of 1986. In particular, intraday call option price changes are translated into implied stock price changes using the American call option pricing model. These intraday implied stock price changes are then compared with actual stock price changes to identify which, if either, market leads the other. After purging the price change series of the effects of bid/ask spreads, multivariate time-series analysis is used to estimate the lead/lag relation between the price changes in the option and stock markets. The results indicate that price changes in the stock market lead the option market by as much as fifteen minutes.

Stephan and Whaley (1990) contend that the Manaster and Rendleman (1982) results may be due to differential closing times between the stock and option markets. Vijh (1990) argues further that Manaster's and Rendleman's methodology suffers from the bid-ask bias as well as the nonsynchroneity. He concludes that not accounting for the bid-ask bounce and the nonsynchroneity between stock and option prices in an ex post study can give the impression that the option prices lead the stock prices even when the two are in equilibrium. Diltz and Kim (1996) document empirical methodology and results regarding price changes in stock and option markets that mitigate problems that may have plagued a similar study by Manaster and Rendleman (1982). Results from their study are consistent with Manaster and Rendleman, in that changes in the current stock price adjust to lagged changes in option-implied stock prices over a period of one future trading day. However, they also detect bi-directional causality. It appears from their work that Manaster and Rendleman's result are not due to a non-synchroneity problem, nor to bid-ask bias. Adding to the controversy, Finucane (1991) finds that S&P 100 index option prices lead the S&P 100 index level during the intraday period.

Easley, O'Hara, and Srinivas (1998) look at the option volume and stock prices to predict the information content of the option market and information lead-lag between markets. They investigate the informational role of transactions volume in options markets. In their paper, they develop an asymmetric information model in which informed traders may trade in options or equity markets. Their empirical findings show that when there is information content in any trade in either stock or options markets; traders in other market follow it in order to capture the benefits of private information. In order to avoid the expiration effect, data of that week are discarded. Intra-day data are used and prediction of the future stock price movement is made also for a maximum of one day. Because the market participants can learn from trades in both markets, they conclude that informed traders trade in both markets. In order to test their conclusion, they suggest testing the basic hypothesis that knowledge of past option trades is valuable in predicting stock price changes. They argue that if, instead, options are used *only* as hedging vehicles, then all option trades would be liquidity based (uninformed) and one would not find any link between option volumes and stock prices.

Easley *et al* (1998) use the technique of causality testing proposed by Granger (1969), and Granger and Newbold (1977) to investigate the relationship between option volume and stock price changes, if one market leads the other, and if so for how long. They identify individual univariate time series using autoregressive integrated moving average (ARIMA) models to generate pre-whitened series and use these data by causal regression models. A set of multiple time series regressions are developed where the dependent variable in one equation is the change in the stock price and the independent variables are the lagged volumes of options from the option market. This regression model defines whether the activities in the options market are followed by the stock market. The other regression model uses the volumes in the options market as the dependent variable and lagged change in stock prices as independent variables to see if the lagged change in the stock price influence the volume in the options market. The constant terms would be expected to pick up any remaining market frictions. According to the specification of their model, the coefficients on the option volume will be statistically significant in a pooling equilibrium when volume is measured as either positive option volume or negative option volume. This is consistent with the prediction that information is reflected in options markets, and some traders expecting a change in the price of underlying stock, trade in specific options first. If this information transfer takes place quickly, then the coefficients of the explanatory variables would be significant.

A null hypothesis is developed that the lagged volumes in options market do not have any predictive power for stock price changes and the hypothesis is tested using likelihood ratio test for the restricted and unrestricted equation system. If the null hypothesis is rejected, a natural question to investigate is the timing and direction of the predictive power of the joint series. This question is addressed by examining the behavior of the individual lag coefficients jointly. In particular, the joint null hypothesis that the series of lagged change in stock prices and lagged volumes of options is only contemporaneously related. A simple t-tests of the significance of the individual coefficients.

In the empirical testing, they use a 5-minute interval data. Within each interval, buys of the puts, buys of the calls, and sells of calls are aggregated separately. They include all option series for which sufficient trading volume exists to make our statistical inferences meaningful.

The main result of the paper is that total, put or call option volumes do not have information content can not be rejected and negative or positive options volumes do not contain information about future stock prices is rejected. The negative option effects are stronger (in terms of statistical significance), suggest that options market may be relatively more attractive venues for traders acting on “bad” news.

The paper also finds that the stock price changes lead the option volumes by almost 20 minutes, and traditional option volumes do not lead stock price changes. It is shown that positive changes in stock price are likely to be followed by increases in call option volume. The leading effect of call option volume, however, is not significant. The signs on the coefficients for the put option volume suggest that a rise in the stock price reduces trading activity in puts. However, informed trading may take place in deep in the money or deep out of the money options that are not otherwise heavily traded.

Jennings and Starks (1986) study the effects of option trading on the behavior of underlying stock prices. The study is conducted on trading of securities around their earnings announcements. They choose 150 with options and 84 non-option firms for three months period in 1981, and 180 with option and 99 with non-option firms for same periods in 1982. Their findings are consistent with the hypothesis that the common stock of firms with exchange-listed options is associated with a different price adjustment process than that of non-option firms. The stock prices of non-option firms take longer time to adjust to earnings announcements than the prices of control portfolios of option firms. This supports the arguments that the existence of the option market is useful in disseminating information.

Nofsinger and Prucyk (1999) examine the impact of scheduled macro economic news announcements on both OEX index options and 50 most liquid individual equity options volume. Using the trading volume predictions of Kim and Verecchia (1991) and Easley, O'Hara, and Srinivas (1998) models, they empirically examine the reaction of the option market to scheduled macroeconomic announcements. By sorting the announcement dates by return, they create both bad new and good news samples. In the bad news sample, the high OEX option volume of post-announcement trades and high level of put-option buying and call-option selling in the pre-announcement periods indicate either the presence of informed investors or a high level of information surprise in the news. Further partitioning of the bad news sample by information surprise supports the informed trader hypothesis. The volume reaction of option trades is asymmetric. That is, while the trading increases substantially after bad news is released, the volume increases by a much smaller amount after good news is released. However, there are high levels of call-option buying and put-option selling before the good news. This is consistent with their informed trader hypothesis.

Nofsinger and Prucyk (1999) also examine the option implied volatility before and after the anticipated announcements. In general, they find that these announcements temporarily increase volatility. Following Barcley and Warner (1993), they also examine the 'stealth trading' of informed traders, that is, they classify trades as small, medium, or large volume trades. Nofsinger and Prucyk (1999) do not find any evidence that informed traders camouflage their knowledge by trading in medium trade sizes. They emphasize that not all types of macroeconomic indicators interest option traders. Of the macroeconomic indicators announced during option trading hours, CPI and new home sales elicit highest trading response. Factory orders and construction spending also associated with increased trading volume.

Kumar, Sarin and Shastri (1992) investigate the behavior of stock and option prices around block trades in stocks. Using intra-day data, they have identified about 156 uptick block trades and 211 downtick block trades on a sample of 80 stocks chosen from NYSE listed stocks. Uptick and downtick rules are used to classify blocks into buyer initiated and seller initiated blocks and the analysis of option price behavior is based on the shortest maturity options that were listed at the time of the block trade. The analysis of option and stock prices around block trades is based on the examination of average returns over twelve fifteen-minute intervals starting one hour before and ending two hours after the block trade using the bootstrap procedure suggested in Barcley and Litzenberger (1988). The block interval (0:00 to 0:14) is associated with a significant abnormal return in stocks, calls, and puts for both downtick and uptick block trades. As expected, the returns are in the direction of the block for stocks and call options and in the opposite direction for put options. This finding is consistent with previous research and indicates that block trades convey private information.

The difference in the behavior of option and stock prices is in the intervals prior to and after the block interval. In the stock market, all adjustments for uptick block trades take place in the block interval, with no other intervals exhibiting significant abnormal returns. For downtick block trades, significant abnormal returns are observed for both the block interval and the interval just prior to the block. In contrast, option prices seem to react over an extended period starting approximately one-half hour before and ending approximately one hour after the block. The reaction is more pronounced for downtick block trades and for put options. The above results imply that the options market takes longer to adjust to the arrival of information implicit in the block. This is consistent with the evidence in Stephan and Whaley (1990). It is also observed that even though the options market takes longer to adjust to the block transaction then does the stock market; it begins this adjustment to this adjustment procedure before the stock market. Option prices start moving in the direction of the block trade approximately thirty minutes before the block trades and that returns are significantly correlated with lead stock returns suggesting that information reflects in option markets first before it is reflected in stock market.

Park, Switzer and Bedrossian (1999), on the other hand, examine the interactions between trading activity of equity options and the volatilities of the underlying equities. A sample of 45 companies with most actively traded equity options at the Chicago Board of Options Exchange from January to July 1991 is selected to conduct the analysis. For each company, equity price variability is compared with its related own trading volume as well as option volume. Park *et al* (1999) show that there exists a positive contemporaneous correlation between trading volume of options and the underlying stock's volatility. Furthermore, they model the relationship between contemporaneous trading activity and conditional volatility using GARCH framework as well as an asymmetric GARCH approach that allows for the direction of price shocks to impact on volatility through leverage effects. Trading activity of the equity options is captured by various indicators, including options trading volume, open interest, and trading volume as a percentage of open interest. The trading activity measures of the underlying equities are also compared to the conditional volatility in order to capture the differential effects of the spot and the derivatives markets. The results show that anticipated trading volume of equity options is associated with volatility of the underlying equity for only a minority of firms in the sample. However, unanticipated trading volume of both stocks and options is found to be positively associated with equity volatility for almost all the firms in the sample. Over all, they find that there is a high degree of integration of the equity and the options markets and trading in the equity options market does not systematically lead to price destabilization in the underlying equity market.

Bessembinder and Seguin (1992) examine the relationship between trading volume of derivatives and the underlying asset's volatility with stock index futures data. Their evidence suggests that futures market trading activity is not associated with an increase in the volatility of the underlying equity index. Indeed they show that forecast as opposed to unexpected trading activity in futures markets has negative impacts on the volatility of the underlying equity market.

Figlewski (1981) provides empirical evidence that short sale constraints affect realized stock returns. He takes the recorded level of actual short interests as a proxy for the amount of short selling there would have been if it had not been constrained, and therefore, the amount of adverse information that was scheduled from the market. For a sample of 414 stocks included in the S&P's 500 index in the 1970s, those with relatively high short interest were found to have significantly lower risk-adjusted returns in the following period than did stocks with relatively low short interest. Figlewski and Webb (1993), using a sample of 342 stocks from the S&P 500 index where some are optionable and some are nonoptionable and have monthly returns data from the period 1974 to April of 1985, argue that introducing options trade can potentially reduce or eliminate the informational effect of short sales constraints, by providing alternative trading strategies for investors with unfavourable information to sell short indirectly.

They find that trading in options contributes to both transactional and informational efficiency of the stock market by reducing the effect of constraints of short sales. They also argue that options trading play an important informational role in the market by helping the market incorporate certain types of information into prices. They find that as options trading plays a role in reducing the impact of short sales constraints, a positive relationship between the existence of options and the average level of short sales exists, due to the hedging activities of options market makers and professional traders.

Also investors with unfavorable information buy put options and write call options instead of shorting the underlying stocks. This is evident from the upward pressure on the put prices and the downward pressure on the call prices, which are reflected in higher implied volatilities for puts than calls at times when short interests are high.

4. Conclusion and Summary

This survey of the current literature provides evidence that the daily option activities contain private information. This is evidence of the presence of informed investors in the option markets, which is not yet reflected in underlying stock prices.

What is evident from this survey is the fact that the market microstructure literature has produced a tremendous amount of theoretical and empirical research to indicate the presence of asymmetrically informed financial markets, to support the hypothesis that informed traders choose one particular market over the other when it comes to information trading, and to prove that different trading activities in different markets do indicate the existence of information trading. While it is understandable that the market microstructure can bring evidence of any information trading quite efficiently, there are some shortcomings in the existing literature.

First, the current market microstructure literature suggests that volume and prices can be examined to identify the presence of information trading. However, it fails to show if it is possible to quantify the value of the private information. In other words, if information trading takes place at a certain security price, uninformed investors can only identify that an information trade took place. They have no way to know the value of the private information.

Second, uninformed investors do not have access to the market microstructure trading data for each stock on each trading day in subsequent trading days. There are thousands of stocks trading in a stock market everyday. Keeping track of real time microstructure trading data to identify any information trading is almost impossible for any uninformed trader. It is only possible for a very small number of traders, mainly institutional traders with adequate resources and technology, to maintain such databases.

Third, derivative trading volumes are also found to be informative. Option volumes can indicate price movements in the underlying stocks to a maximum of 30 minutes. This finding is somewhat confusing and limited. Options are traded for multiple maturity periods and at multiple strikes on each maturity date. If one only looks at total volume to identify information trading, it is not feasible to identify any information from the volume in the following sense. First, trading volumes are related to a particular option maturity date. These trading volumes therefore should indicate probable price movements for the underlying security for that maturity date. Second, volumes are daily activities on options and they cannot be identified as whether informed traders are buying options or selling options, which may be more informative than simple total volumes. In addition, volumes also fail to identify and/or quantify the price movements of the underlying stock for the maturity date. Finally, trading volume is not available as public information for investors at any future date. Only those who have access can investigate the information content.

Appendix A

REFERENCES

Anthoney, J., 1988, The interrelation of stock and options market trading-volume data, *Journal of Finance* 43, 949-964.

Bessembinder, H., K. Chan, and P. Seguin, 1996, "An Empirical Examination of information, Differences of Opinion, and Trading Activity," *Journal of Financial Economics*, 18, pp-105-134.

Bhattacharya, Mihir, 1987, Price changes of related securities: The case of call options and stocks, *Journal of Financial and Quantitative Analysis*, 22, 1-15.

Biais,B. and P. Hillion, 1994, Insider and Liquidity Trading in Stock and Options Markets, *Review of Financial Studies* 7,743-780.

Black, Fisher, 1975, Fact and fantasy in use of options, *Financial Analysts Journal,* 31, 36-41.

Black, Fisher, and Myron Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy,* 81, 637-659.

Blume, Easley, and O’Hara, 1994, Market statistics and technical analysis: Role of volume, *Journal of Finance* 49, 153-182.

Brennan, M., and Cao, 1996, Information, trade, and derivative securities, *Review of Financial Studies* 9, 163-208

Buckle, M.J., A.D. Clare and S.H. Thomas, 1999, "Developing a Trading Rule from the FTSE-100 Stock Index Futures Contract: Evidence in Support of the EMH", *Journal of Business Finance and Accounting*, 26, pp-249-260.

Cao H.H., 1999, "The Effect of Derivative Assets on Information Acquisition and Price Behavior in a Rational Expectations Equilibrium," *The Review of Financial Studies*, 12, 131-163.

Chan, K.A. 1992, "Further Analysis of the Lead-Lag Relationship Between the Cash Market and the Stock Index Futures Market, *Review of Financial Studies*, 5, pp-123-152.

Chen,N.F., Cuny,C.J., and Haugen, R.A., 1995, "Stock Volatility and the levels of the basis and open interest in futures Contracts," *The Journal of Finance*, 50, pp-281-300.

Cherian,J., 1993, Option pricing, self-fulfilling prophecies, implied volatilities, and strategic interaction, Unpublished Ph.D. Dissertation, Cornell University.

Chong, Y.H. and D.F. Hendry, 1986, "Econometric Evaluation of Linear Macro-Economic Models", *Review of Economic Studies*, 671-690.

Detemple, J., and Larry Selden, 1991, A general equilibrium analysis of option and stock market interactions, *International Economic Review* 32, 279-302.

Detemple, J., and Philip Jorion, 1990, Option listing and stock returns, *Journal of Banking and Finance* 15, 647-664.

Easley,David, Maureen O’Hara, and Srinivas P.S., 1998, Option volume and stock prices: Evidence on where informed traders trade, *Journal of Finance*,2, 431-465.

Engle, R., A. Kane, and J. Noh, 1993, "A test of Efficiency for the S&P 500 Index Option Market Using Variance Forecasts," NBER working paper 4520.

Figlewski, S., 1981, "The Informational effects of restrictions on short sales:Some empirical evidence," *Journal of Financial and Quantitative Analysis* 16, pp_463-476.

Figlewski, S. and G.P. Webb 1993, "Options, short sales and market completeness," *Journal of Finance*, 48, pp-761-777.

Flemming,J., Ostdiek, B., and R. Whaley, 1996, "Trading Costs and the Relative Rates of Price Discovery in Stock, Futures and Options Markets", Journal of Futures Markets, 16, pp-353-387.

Granadier, S.R., 1999, "Information Revelation Through Option Exercise," *The Review of Financial Studies*, 12, 95-129.

Grossman, Sanford, 1988, "An Analysis of the Implications for Stock and Futures Price Price Volatilitiy of Program Trading and Dynamic Hedging Strategies, *Journal of Business*, 61, pp_ 275-298.

Guo Dajiang, 1999 " Dynamic Volatility Trading Strategies in the Currency Option Market Using Stochastic Volatility Forecasts", A part of Ph.D. thesis, University of Toronto.

Harvey, C.R., and R. Whaley, 1992, "Market Volatility Prediction and the Efficiency of the S&P 100 index Option Market," *Journal of Financial Economics*, 31, pp_43-73.

Harris, L., and A. Raviv, Differences of opinion make a horse race, *Review of Financial Studies* 6, 473-506.

Hietala, P., E. Jokivuolle, and Y. Koskinen, 2000, "Informed Trading, Short Sales Constraints, and Futures' Pricing," Working paper, INSEAD.

Hull,J.C. Introduction to Futres and Options markets, 1999, (Prentice Hall, New Jersey, USA)

Krauss, A. and M. Smith 1996, "Heterogeneous Beliefs and the effects of replicable Options on Asset Prices," *Review of Financial Studies*, 8, pp-723-756.

Kumar,P., and Seppi,D., 1994, "Information and Index Arbitrage," *Journal of Business*, 67, pp-481-509.

Lorne Switzer, Tae Park and Rob Bedrossian ,1999, 'The interactions between trading volume and volatility - evidence from the equity options market' , *Applied Financial Economics* (Vol 9, pp. 627-637).

Manaster, Stephen, and Richard J. Rendleman, 1982, Option prices as predictors of equilibrium stock prices, *Journal of Finance*,37, 1043-1057.

Mandelbrot,B. 1966, Forecasts of Future Prices, Unbiased Markets, and Martingale Models. *Journal of Business*, 39, 242-55.

Milgrom, Paul, and Nancy Stockey, 1982, Information, trade and common knowledge, *Journal of Economic Theory*, 26, 17-27.

Merton, R.C. 1973, "The Relationship Between Put and Call Option Prices: Comment", *Journal of Finance*, 31, pp-369-381.

Merton, R.C. 1981, "On Market Timing and Investment Performance: I. An Equilibrium Theory of Value for Market Forecasts", *Journal of Business*, 54, 363-406.

Merton, Scholes, and Gladstein, 1978, " The Returns and Risk of Alternative Call Option Portfolio Investment Strategies", *Journal of Business,* 51, pp-183-242.

Mayhew,S., A. Sarin, and K. Shastri, 1995, The allocation of informed trading across related markets: an analysis of the impact of changes in equity-option margin requirements, *Journal of Finance* 505, 1635-1654.

Morris, S., A. Postlewaite, and H.S. Shin, 1995, "Depth of Knowledge and the Effect of Higher Order Uncertainty," *Economic Theory*, 6, 453-467.

Puttonen,V., 1993, "Short Sales Restrictions and the Temporal Relationship Between Stock Index Cash and Derivatives Markets," *The Journal of Futures Markets*, 13, pp-645-664.

Raynauld,J. and J. Tessier, 1984, "Risk Premiums in Futures Markets: An Empirical Investigation", *Journal of Futures Markets*, 4, pp-189-211.

Skinner, D.J., 1989, "Options markets and Stock market volatility" *Journal of Financial Economics*, 23, 61-78.

Skinner, D.J, 1990, "Options Markets and Information Content of Accounting Releases", *Journal of Accounting and Economics*, 13, 191-211.

Stephen, Jens A., Robert E. Wheley,1990, Intraday price change and trading volume relations in the stock and stock options markets, *Journal of Finance*,44, 115-134.

Stephan,J., and R. Whaley, 1989, Intraday price change and trading volume relations in the stock and stock option markets, *Journal of Finance* 45, 191-220.

Stoll, H.R.,and Robert E. Whaley, 1990, The dynamics of stock index and stock index futures returns, *Journal of Financanial and Quantitative Analysis 25,* 441-468.

Subrahmanyam,A., 1991, "A Theory of Trading in Stock Index Futures," *Review of Financial Studies*, 4, pp-17-51.

Vijh,A., 1990, Liquidity of the CBOE equity options, *Journal of Finance* 45, 1157-1179.